



A comment on “Liberalization and food price distribution: ARCH-M evidence from Madagascar” (Barrett, 1997)

Véronique Meuriot¹, Abdoul Salam Diallo²

¹ Cirad ES, ART-Dev UMR 5281, ² Université Montpellier 1, LAMETA UMR 5474

Abstract

This paper revisits that of Barrett, published in *Food Policy* in 1997. Even if Barrett resorted to the use of the appropriate methodology, ARCH-M models, it would appear that he misinterpreted its philosophy, just as he misspecified the variance equation of the ARCH. This led him to a spurious modeling at several levels, methodological and theoretical. Using food price time series (as Barrett did), we first explain the inconsistencies in Barrett (1997) and then we propose three modeling procedures: that of Engle, Lilien and Robins (1987) and then two others similar to Barrett's, but differing by the fact that one is carried out with good identification of the time series data generating process, and the second without. These three models allowed us to apprehend the gap between results of a “correct” ARCH-M model and those of Barrett. The interest of this comment on is to highlight few irregularities of drawn conclusions that were subject to economic recommendations at that time, and also that are being largely replicated in agricultural economic papers.

Keywords: volatility, ARCH, misspecification error, publication bias.

Titre

Un commentaire sur l'article de Barret “Liberalization and food price distribution: ARCH-M evidence from Madagascar”

Résumé

Cet article revisite le papier de Barrett publié dans *Food Policy* en 1997. Même si Barrett a eu recours à la méthodologie appropriée, la modélisation ARCH-M, il semble qu'il ait mal interprété sa philosophie, ainsi qu'à une mauvaise interprétation de l'équation de la variance du ARCH. Ceci l'a conduit à une modélisation erronée à plusieurs niveaux, méthodologique et théorique. À partir de séries temporelles de prix de denrées alimentaires (à l'instar du travail de Barrett), nous expliquons tout d'abord les incohérences du papier de Barrett (1997) et proposons ensuite trois procédures de modélisation : celle d'Engle, Lilien et Robins (1987), puis deux autres semblables à celle de Barrett, l'une réalisée avec une identification correcte du processus générateur des séries temporelles, l'autre avec une modélisation « à la Barrett ». Ces trois modèles nous ont permis d'appréhender l'écart entre les résultats d'un modèle d'ARCH-M « correct » et ceux obtenus par Barrett. L'intérêt de cet article est de pointer certaines irrégularités notamment dans les conclusions de l'auteur qui en tirait des recommandations de politiques économiques. Cette procédure a été reprise dans de nombreux articles d'économie agricole générant ainsi un biais de publication.

Mots-clés : volatilité, ARCH, erreur d'interprétation, biais de publication.

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Auteur correspondant : veronique.meuriot@cirad.fr

1. Introduction

In 1997 Christopher Barrett proposed testing the effects of liberalization measures of several food prices in Madagascar. As from his introductory section, he presented the issues subsequently investigated: *“The [...] question, curiously overlooked thus far, is whether market-oriented reforms indeed stimulated food prices, as is generally presumed.”* (1997, p. 155). He pointed out the absence of any “well-articulated” theory allowing to understand how stochastic behavior of prices responded to economic liberalization. The author was looking for an estimation method to address the liberalization effects on agricultural commodity prices, which he entitled “prices response to liberalization mechanism”. His research logically led him to assume that these prices exhibited an increase in mean and a decrease in variance. In other words, the price level increased more homogeneously since the observed average spread of these prices was reduced. He supposed that there existed an influence mechanism of price risk on the average level of prices.

Barrett (1997) resorted to the use of ARCH-M models (*AutoRegressive Conditional Heteroskedasticity in Mean*) by Engle, Lilien and Robins (1987), which account for fluctuations of the mean in the conditional information, attempting to capture the liberalization effects on food prices using volatility measurements on the price series concerned. And based on this modeling procedure, the author reached a conclusion stating that liberalization of commodity markets has had diversified short run effects on food prices. Hence, the observed differentiated impacts on food prices are also identified with respect to the various studied regions, as well as to the various seasons. As for its long run impact on prices, drawn conclusion is that liberalization exerts significant influence on average levels reached by food prices, as well as their average variability around their mean (in other words, liberalization primarily contributes to increasing the average variability of food prices). And finally, results reached by this paper revealed convergence of all studied regions’ prices towards a common average value, a phenomenon that the author linked to the intrinsic dynamics of the prices (dictated by market forces).

In our attempt to revise his results, we briefly point out few methodological and theoretical inaccuracies found in Barrett’s paper in section 2. In a third section, we will propose comparison on three models estimation results: the ARCH-M model estimation as suggested by Engle, Lilien and Robins (1987), Barrett’s proposed model with correct identification of the data generating process of the series and finally a third model that replicates Barrett’s procedure in this paper. We conclude on the differences in results and the economic consequences of policy recommendations by Barrett.

2. Where the problem lies

It would seem that Barrett’s understanding of theoretical elements proposed by Engle (1982) then Engle, Lilien and Robins (1987) led him to certain misinterpretations of the volatility process. By reintroducing the exogenous variables in variance equation, despite prior inclusion in the mean equation, the author inserts a certain redundancy in his model. This redundancy misrepresents the philosophy of ARCH modeling as developed by Engle (1982) and deviates from the concept of volatility as commonly used in time series. The resulting estimates cannot lead to the measurement of volatility, unlike Barrett’s intuition.

Plus, the epistemological consequences that arise from this misinterpretation are twofold: first, the inadequacy on the econometric tool can prove to be a real drawback since it leads, in this case, to conclusions of economical and geopolitical nature. These conclusions will be used in many cases to assist political decision-makers in designing economic policies. Then, the misinterpretation in its theoretical form will be replicated in many papers, thus generating publication bias (Barrett’s paper is broadly used and cited till today).

2.1. Methodological errors ...

The methodological developments suggested by Barrett are at the very least surprising. Results of his preliminary analysis are shown in appendix of the paper (p. 172-173). Thus, we can read that all his series, subject to volatility analysis, are structured following an autoregressive process of order 1, and that tests carried out on regressions residuals (mean equations) indicate that said residuals are white noises processes:

“The specification of the system proceeded by first testing for stationarity of the dependent variables. Augmented Dickey-Fuller tests for each of the five series generated test statistics well below 5% critical values, leading one to reject the null hypothesis of non-stationarity. The next step involved Box-Jenkins analysis of the sample autocorrelations and partial autocorrelations. This suggested an AR(1) structure in each case. The Ljung-Box-Pierce portmanteau Q-statistics associated with the residuals generated from the above model using AR(1) specification were all below the critical χ^2 values, so the null hypothesis that the residuals are white noise cannot be rejected.” (p. 172).

Whatever be the case, if as claimed, residuals appear to be white noise process, then they cannot be heteroskedastic. Furthermore, homoskedastic series cannot be subject to ARCH modeling.

On another hand, questions also arise concerning stationarity investigations relating to price series used in Barrett works. Are they really structured as AR(1) processes? The observed situation stems from one of two things: either the residuals are white noise processes, or the structures of the initial prices series are incorrectly identified. Let us note that volatile prices (volatility being define as time-dependent variance process), necessarily exhibit non-stationary behaviors (since volatility is a consequence of non-stationarity¹). Regardless the outcome, Barrett undertakes “spurious regressions” as addressed by Granger and Newbold (1974): the methods used are not consistent with the econometric issues. So, his study is invalidated by the very form of the studied series.

2.2. Theoretical errors ...

It seems that Barrett tried to rewrite in a compact form theoretical formalization of the ARCH-M process as given in Engle, Lilien and Robins (1987). Thus, he made two interpretation mistakes (p. 159):

- Equation of the initial price process in Barrett (1997) is:

$$P_{it} = \beta_0 + \beta_1 P_{it-1} + \sum_i \beta_i X_{it} + \delta h_{it}^{1/2} + u_{it}$$

This writing is wrong or at least non rigorous. He omits some regional indices. His equation would thus be written as:

$$P_{it} = \beta_{i0} + \beta_{1i} P_{it-1} + \sum_{i=2} \sum_j \beta_{ij} X_{it} + \delta_i h_{it}^{1/2} + u_{it}$$

- Equation of the conditional variance includes exogenous variables of the initial process in addition to the residual and to the one-period lagged endogenous variable:

$$h_{it} = \alpha_0 + \alpha_1 u_{it-1}^2 + P_{it-1} + \sum_i \gamma_i X_{it}$$

while the ARCH equation is: $h_t = \alpha_0 + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2$

¹ A stationary variable is one that exhibits invariant mean and constant variance over time. Volatility on the other hand (also considered as heteroskedasticity) refers to a process exhibiting time dependence pattern of its variance

Indeed, in the paper of 1982, Engle explained that the variance of the residual process (h_t) was conditional on the information available. Engle then gave the writing (p. 989):

$$\begin{aligned}\varepsilon_t &= y_t - x_t\beta \\ h_t &= h(\psi_{t-1}, \alpha) \\ \text{and thus } h_t &= h_\varepsilon(\varepsilon_{t-1}, \dots, \varepsilon_{t-p}, \alpha) h_x(x_t, \dots, x_{t-p})\end{aligned}$$

But the above expression of h_t is its functional form, and not that of the estimates given earlier in the paper: $h_t = h(\varepsilon_{t-1}, \varepsilon_{t-2}, \dots, \varepsilon_{t-p}, \alpha)$. The variable h_t is the variance of the residual process ε_t across time, itself resulting from the computation of the mean equation. However, Engle used a vector denoted \tilde{Z}_t to describe autoregressive processes of residuals over the first lag (Engle, 1982, p. 997) : $\tilde{Z}_t = (1, e_{t-1}^2, \dots, e_{t-p}^2) / h_t^i$. But in no way were the exogenous variables to be introduced in the variance equation – nor the first order lag of the endogenous, P_{t-1} – of the ARCH model. In the same way, Engle, Lilien and Robins reminded that (1987, p. 395-396):

“The general setup is given by

$$(8) Y_t | X_t, \Pi_t \approx N(\beta' X_t + \delta h_t, h_t^2)$$

$$(9) h_t^2 = \alpha' W_{\eta_t} + \gamma' Z_t$$

where X_t and Z_t are $k \times 1$ and $j \times 1$ vectors of weakly exogenous and lagged dependent variables, as in Engle, Hendry, and Richard (1983). The vector Z_t includes a constant whose coefficient represents the constant variance component of h_t . The $p \times 1$ vector $\eta_t' = (\varepsilon_{t-1}^2, \dots, \varepsilon_{t-p}^2)$ where ε_t are the disturbances given by $Y_t - \beta' X_t - \delta h_t$.”

Barrett seems not to have seen that in ARCH modeling, the residual process was considered in turn as a univariate ARMA process for which one seeks the structure².

These two forms of misinterpretation led Barrett to estimate something other than the traditional volatility process (or conditional variance) of a price series. Beyond the methodological inconsistency, he also introduced an information redundancy into the h_t process which considerably distorted his work. His misinterpretation of the h_t process, and of its origin, led him to reintroduce the exogenous variables of the initial price process in the expression of the conditional variance whereas this process already results from it. Hence, the h_t structure modeled by Barrett cannot be considered as representing the volatility component of the initial process. Barrett considered twice the set of available information and introduced an informative loop into his model. He artificially created an identification and specification problem. These models fall into the category of the spurious regressions. Not only did he use methods based on heteroskedasticity to model variables that did not contain any, he also carried out erroneous estimations, biased by the reintroduction of an information set (exogenous variables) into a step of the procedure where he shouldn't have, since this information was already used to model the deterministic component of the price series.

² Let us note that these comments remain valid in the multivariate case where the main difference lies in the addition of the cross products of the error terms of the various equations.

By introducing deterministic information into the conditional variance, Barrett created anomalies that flawed his future results. While he intended to study volatility, it seems that he studied anachronistic shocks: on one hand, the exogenous variables altered the fulfillment of volatility, and on the other hand the use of contemporaneous values of exogenous variables (at time t) in the determination of past observations created a coherence bias; indeed what interpretation could one possible make of *current effects influencing past realization of an economic phenomenon*? There truly exists a causal discrepancy. This assessment is, at the least disturbing, all the more so as conclusions of economic nature are suggested with respect to the obtained econometric estimates.

3. Comparison of the models: Engle's ARCH-M versus Barrett's « model »

In order to point out inconsistencies and modeling bias that Barrett (1997) suffers, we commutated three different volatility models. We first, estimated an ARCH-M model as formalized by Engle, Lilien and Robins (1987). Then, modeling procedure *à la* Barrett (*i.e.* trying to replicate error on identification of the data generation process) was carried out, and finally a corrected version of the previous model. Since we were unable to get hold of the same data used in Barrett (1987) paper, we resort to alternate series, namely monthly national price of the local husked rice in Senegal from January 1995 to August 2009, and the exchange rate of the CFA frank to the dollar over the same period. The endogenous variable was the monthly national price of the local husked rice in Senegal, while the exchange rate was used as exogenous variable of the price of rice. The two series were found to be non-stationary (integrated of order 1)³

Although interpretation is not possible based on “Barrett's models” results, they however displayed distortions comparatively to the ARCH-M model. Thus, we could observe that:

³ Data and prior analysis are presented in appendix A.

Table 1 – Comparison of the models

		ARCH-M	Barrett-like model	
			With incorrect identification AR(1)	With correct identification I(1)
Mean equation	Autoregressive dependence	Autoregressive dependence at 7 months: a major change in price level will take 7 months in average to be accounted for. Thus, the implementation of an economic measure today will be effective only in 7 months.	Autoregressive dependence at 1 month: a major change in price level will take 1 month in average to be reflected. Thus, the implementation of an economic measure will have a quasi immediate effect.	Ditto ARCH-M
	exchange rate (exogenous variable)	is not related to the price of rice.	Weakly, but negatively related to the price of rice.	Ditto ARCH-M
	Impact of the Volatility process' dynamics	Negative GARCH coefficient: the higher the degree of instability, the more it induces a fall in prices. significant ⁴	non significant	Ditto ARCH-M
	Trend	Significant and positive	Non significant and negative	Non significant and positive
	Constant	Non significant and negative	Significant and positive	Ditto ARCH-M
Variance equation	Volatility	Variance at time (t) is conditional to forecasting error (agent's expectation) : ARCH(1) = 19,15% ARCH(2) = 49,99% Distortion on the contemporary value of prices induced by historical values (volatility) account for almost 70% of total variance dynamics	ARCH(1) = 29,94% Introduction of the exogenous variables distorts estimated value of the ARCH coefficient	ARCH(1) = 78,30% Introduction of the exogenous variables distorts the estimate of the ARCH coefficient
	R ²	0.0876	0.9332	-0.0019

4. Conclusion

Barrett wished to measure the effect of liberalization on the food prices, but his misinterpretations had serious consequences, all the more so as his results led to economic policies relating to the effects of liberalization of African food prices. From the distorted estimates and inconsistencies stemming from his modeling procedure, we could not validate his conclusions. As indicated in the summary of his article *"There is no well-articulated theory of how stochastic food prices respond to economic liberalization measures, a surprising oversight in the vast literature on market-oriented reforms."*

⁴ Proceeding as Barrett's did, this significant GARCH coefficient would indicate that, to some extent, liberalization has managed to stabilize the market. Note however in Barrett's models (1997), none of these coefficients are significant.

Amongst conclusions drawn from his analysis, one highlighted most his misunderstanding of the ARCH models: *“Likewise, one sees in the trend coefficients of the conditional variance equations that price volatility grew uniformly in the pre-reform period, as the parastatal distribution system became increasingly unreliable, then declined uniformly through the liberalization era. [...] The evidence points strongly in the direction of private traders exerting new, substantial influence over food pricing, although this evidence should not be misinterpreted as a finding of efficient markets.”* (p. 169)

However, the conditional variance equation does not include exogenous variables, no more than a trend. Indeed, at the time economists thought that market liberalization was going to enhance small local African producers’ life style. But today, many are those who revised this point of view, rather admitting that it has impoverished said producers and vulnerable populations due to structural volatility.

Econometric analysis of price volatility can no longer be restricted to the sole measure of ARCH coefficient in a conditional variance equation. Indeed, one needs to address the issue of persistence of this volatility through addition of GARCH coefficients⁵ (and their significance). Thus, volatility (variance equation) can be interpreted on two levels:

- *Current* volatility, represented by the ARCH coefficients, which translates a short-term effect of the disturbing events on the price evolution. It makes it possible to catch the common effects (exogenous). It is a volatility induced by *spontaneous but controllable behavior* of actors on the market.
- *Structural* volatility, represented by the GARCH coefficients, which measures the degree of persistence of volatility over time. It is a volatility induced by *noncontrollable behavior over time* of actors on the market.

Identifying Barrett’s confusion can be quite a challenge since his analysis seems perfectly coherent until *his* writing of the ARCH-M model. The use of this type of model was perfectly justified in regards to his object of study. The economic conclusions reached were perfectly logical and corroborated his former analysis. However, it would seem that the study carried out is only merely an *illusion* of volatility analysis. Although Barrett measured ARCH coefficients at a given time of his models – a clear sign of volatility –, his estimates were completely distorted by the misspecification bias his model suffers, thus rendering obtained results erroneous, as well as inferred conclusions inadequate. Unfortunately, at the light of his study, not only did Barrett draw economic policy recommendations, his paper was (and still is) widely cited since 1997.

⁵ These coefficients were tested in our model and were not significant.

Appendix A –ARCH modeling methodology (1982)

ARCH modeling aims at describing the « distortions » induced by anticipative behaviors of the economic agents. This approach is closely related to the financial markets on which the practices of actors result in nondeterministic but conditional information which generates erratic behaviors associated with gains or risk premium. These erratic behaviors are located in the variance process of the studied economic series. They are characterized by the presence of a heteroskedastic structure of this variance. The presence of this heteroskedasticity means that the process is exposed to *non anticipated* behaviors at the margin. Thus, the process violates *de facto* a fundamental hypothesis on the nature of the innovations process. The analyst must thus study the residuals of the process, in order to identify and to incorporate the additional structure contained in regression errors, by regarding it as a fully temporal process. The ARCH method then allows modeling this new time series by seeking the nature of the autoregressive process structuring it. This autoregressive structure is believed to describe the dynamics of anticipative behaviors of the economic agents over time.

Engle is confronted to three methodological difficulties related to heteroskedasticity:

- Taking into account changes in macroeconomic models (or including rational expectations of economic agents), *i.e.* models with conditional variance changing over time,
- Reasoning on the importance of the conditional distribution to available information,
- Introducing the non-linearity in order to be able to study the alternation of periods of clusters of high volatilities and those of low volatilities.

Although the founding paper for ARCH models was published in 1982 in *Econometrica*, conditional heteroskedasticity related issues had been dealt with by Engle himself since 1979. His rationale is perfectly explicit: *“These are zero-mean, serially uncorrelated processes with non-constant conditional variances to past information, but constant unconditional variances. [...] To test whether the disturbances follow an ARCH process, the Lagrange multiplier procedure is employed. The test is based simply on the autocorrelation of the squared OLS residuals.”* (1982, p. 987)

ARCH models thus meant to model volatility varying over time. Conditional volatility of returns at period t is expressed as a linear function of square past observations. Thus, Engle defined a process which takes into account the phenomenon of conditional heteroskedasticity by extending the traditional bilinear processes introduced by Granger and Andersen (1978).

From the traditional expression of the model, Engle concentrates on the residual series, which contains the heteroskedastic structure since it results from the computation of an initial model (mean equation) between endogenous and exogenous variables.

Let $r_1, r_2, r_3, \dots, r_n$ be independently and identically distributed random variables (i.i.d) representing financial returns of a given asset. Let $F(r) = \Pr(r_t < r / \Omega_{t-1})$ the cumulative distribution function conditional to the informational set Ω_{t-1} available at time $(t-1)$. Suppose that $\{r_t\}$ follows a stochastic process:

$$r_t = \mu_t + \varepsilon_t = \mu_t + h_t^{1/2} z_t$$

$$\text{where } \varepsilon_t = h_t^{1/2} z_t$$

$$\text{and } z_t \sim N(0,1)$$

$$\text{with } h_t = \alpha_0 + \sum_{i=1}^p \alpha_i \varepsilon_{t-i}^2$$

and (p) is the order of the ARCH process. Let r_i be the partial autocorrelation of rank i of ε_t^2 , then the ARCH process will be of order (p) if $r_i = 0, \text{ for } i > p$. This reasoning is the basis of what is commonly called “ARCH(p) effect” which consists in testing the null hypothesis of white noise ($r_i = 0, \text{ for } i = 1 \dots p$) against the alternative ($\exists i / r_i \neq 0$).

Appendix B –Barrett’s errors

Barrett’s ARCH-M equations (1997, p. 159)

$$\begin{aligned}
 P_{it} &= \beta_0 + \beta_1 P_{it-1} + \beta_2 \text{TREND}_t + \beta_3 \text{ER}_t + \beta_4 \text{BP}_t + \beta_5 \text{BUF}_t + \beta_6 \text{STRIKE}_t \\
 &+ \sum_{i=1}^3 \Theta_i S_t + \sum_{i=1}^r \phi_i R_i + \delta h_{it}^{1/2} + u_{it} \\
 u_{it} &\sim \text{iidN}(0, h_{it}) \\
 h_{it} &= \alpha_0 + \alpha_1 u_{it-1}^2 + P_{it-1} + \gamma_2 \text{TREND}_t + \gamma_3 \text{ER}_t + \gamma_4 \text{BUF}_t + \gamma_5 \text{STRIKE}_t \\
 &+ \sum_{i=1}^3 \omega_i S_t + \sum_{i=1}^r \varphi_i R_i.
 \end{aligned} \tag{1}$$

Example of Barrett’s ARCH-M models (1997, p. 161)

Table 1 ARCH-M estimates of real dried bean prices

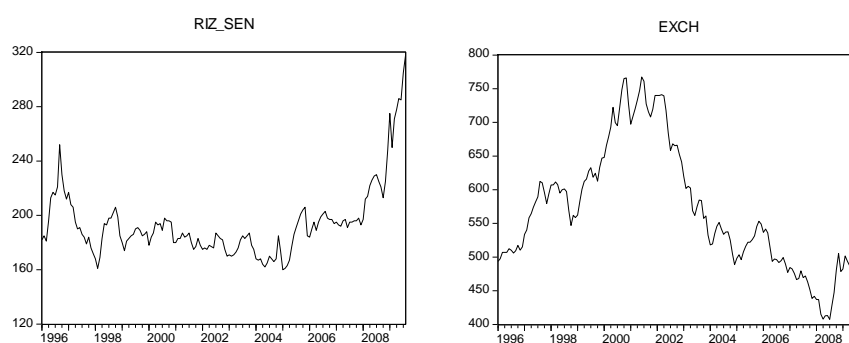
	Pre-reform period		Liberalization period	
	Mean	Variance	Mean	Variance
Constant	226.30 (0.46)	873.90 (0.07)	223.90 (1.79)	438.40 (1.21)
P_{t-1}	0.05 (0.07)	4.48 (31.1)	0.93 (0.02)	4.55 (804.1)
TREND	4.59 (0.59)	2.61 (0.95)	0.002 (0.08)	-6.08 (217.4)
ER	0.86 (0.25)	-2.62 (38.2)	0.04 (0.01)	-1.73 (2357)
BP	-0.21 (0.21)		0.02 (0.08)	
BUF			-1.18 (0.56)	-0.34 (0.10)
STRIKE			-1.96 (1.60)	0.09 (0.02)
δ (risk term)	0.96 (16.0)		0.08 (0.28)	
α_1 (ARCH term)		0.02 (14.3)		0.14 (501.2)
Regional dummies				
Vakinankaratra	-30.2 (2.77)	103.6 (0.03)	-2.03 (1.64)	-0.12 (0.01)
Fianarantsoa	14.5 (2.78)	0.9 (0.02)	-3.46 (1.62)	-0.11 (0.01)
Mananjary	83.4 (2.71)	-323.3 (0.28)	-1.67 (1.74)	-0.03 (0.01)
Farafangana	100.3 (2.79)	-320.4 (0.02)	0.63 (1.65)	-0.11 (0.02)
Ambat’zaka	100.7 (2.77)	-267.1 (0.02)	-0.67 (1.55)	0.90 (0.21)
Mahajanga	154.2 (3.49)	-48.9 (0.00)	1.81 (1.52)	-0.01 (0.11)
Antsohihy	80.6 (2.84)	-126.7 (0.02)	-2.39 (1.63)	-0.08 (0.02)
Toliary	-82.2 (3.40)	1254.0 (0.43)	4.52 (1.52)	-0.05 (0.03)
Antsiranana	130.9 (3.33)	67.4 (0.01)	-3.41 (0.99)	-0.06 (3.48)
Antalaha	188.0 (14.9)	-536.7 (0.04)	1.05 (4.84)	0.21 (0.65)
Seasonal dummies				
April–June	86.2 (0.23)	-472.7 (0.05)	-2.17 (0.09)	-0.14 (20.9)
July–September	5.61 (0.21)	68.6 (0.02)	2.37 (0.88)	0.12 (19.0)
October–December	66.9 (0.23)	-264.3 (0.03)	-0.54 (0.32)	2.18 (0.77)
n	264		792	
R^2	0.81		0.97	

Asymptotic standard errors in parentheses.

Appendix C – Data and econometric results

Data tables

Name	Price of rice in Senegal	Exchange rate
Variable	Riz_sen	Exch
Type	endogenous	exogenous
Period	January 1996 to august 2010	
Frequency	monthly	
Identification	I(1)	I(1)



Identification : unit root test

	Local rice		Exchange rate	
	Level	First difference	Level	First difference
UR test (ADF)	0.324602 (-1.942655) [0.7782]	-11.54886 (-1.942666) [0.0000]	-0.215510 (-1.942677) [0.6073]	-9.083773 (-1.942677) [0.0000]

Tests statistics significant at the 5%, with (tabulated critical value) and [critical probability]

Diagnostic des résidus :

Tests	OLS model	ARCH-M model
Durbin-Watson	1.686370 {d1 = 1.68 ; d2=1.79}	1.485639 {d1 = 1.68 ; d2=1.79}
Portmanteau (2)	3.4399 [0.179]	2.7036 [0.259]
Portmanteau (4)	6.0347 [0.197]	3.0759 [0.545]
Portmanteau (8)	8.7225 [0.366]	3.8868 [0.867]
ARCH-LM test (4)	51.05402 [0.000000]	1.934217 [0.858170]
Normality test	Skew : -0.060324 Kurt : 12.69182 JB : 657.6217 [0.00000]	Skew : 0.134001 Kurt : 4.902623 JB : 25.84261 [0.000002]

Tests statistics significant at the 5%, with [critical probability]

Appendix D – Models estimates

ARCH-M model by Engle, Lilien and Robins (1987)

Dependent Variable: DRIZ_SEN

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	-0.018862	0.007701	-2.449139	0.0143
DRIZ_SEN(-7)	-0.164274	0.030804	-5.332868	0.0000
DEXCH	0.020057	0.029557	0.678591	0.4974
@TREND	0.019027	0.010001	1.902495	0.0571
C	-1.122826	1.081088	-1.038607	0.2990
Variance Equation				
C	23.73880	3.119092	7.610742	0.0000
ARCH(1)	0.191509	0.119416	1.603722	0.1088
ARCH(2)	0.499900	0.134601	3.713928	0.0002
R-squared	0.095246	Mean dependent var		0.226190
Adjusted R-squared	0.055863	S.D. dependent var		9.820974
S.E. of regression	9.543729	Akaike info criterion		6.837834
Sum squared resid	14573.24	Schwarz criterion		6.986594
Log likelihood	-566.3781	Hannan-Quinn criter.		6.898208
F-statistic	2.406229	Durbin-Watson stat		1.538159
Prob(F-statistic)	0.022830			

ARCH-M model using Barrett's procedure (1997)

Wrong identification of generating process: AR(1) instead of I(1)

Dependent Variable: RIZ_SEN

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	-0.035794	0.018664	-1.917777	0.0551
RIZ_SEN(-1)	0.985734	0.046346	21.26889	0.0000
EXCH	-0.013116	0.006426	-2.040996	0.0413
@TREND	-0.001278	0.018168	-0.070323	0.9439
C	12.87613	7.592619	1.695875	0.0899
Variance Equation				
C	-65.16783	54.67015	-1.192018	0.2333
RESID(-1)^2	0.299376	0.113029	2.648655	0.0081
RIZ_SEN(-1)	1.082892	0.258082	4.195916	0.0000
EXCH	-0.139703	0.046249	-3.020657	0.0025
@TREND	-0.243907	0.182004	-1.340123	0.1802
R-squared	0.933234	Mean dependent var		201.8000
Adjusted R-squared	0.929593	S.D. dependent var		38.63460
S.E. of regression	10.25145	Akaike info criterion		6.878549
Sum squared resid	17340.23	Schwarz criterion		7.059394
Log likelihood	-691.8731	Hannan-Quinn criter.		6.951905
F-statistic	256.2592	Durbin-Watson stat		1.410812

Right identification of generating process: I(1)

Dependent Variable: DRIZ_SEN

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	-0.015998	0.004354	-3.674370	0.0002
DRIZ_SEN(-7)	-0.102925	0.045133	-2.280451	0.0228
DEXCH	-0.009211	0.037223	-0.247449	0.8046
@TREND	0.011343	0.010227	1.109211	0.2673
C	-0.346460	0.924927	-0.374581	0.7080
Variance Equation				
C	13.87174	8.543142	1.623728	0.1044
ARCH(1)	0.783045	0.146406	5.348466	0.0000
DRIZ_SEN(-7)	0.179035	0.261631	0.684303	0.4938
DEXCH	-0.471427	0.300753	-1.567489	0.1170
@TREND	0.161260	0.077849	2.071447	0.0383
R-squared	-0.001880	Mean dependent var		0.226190
Adjusted R-squared	-0.058949	S.D. dependent var		9.820974
S.E. of regression	10.10630	Akaike info criterion		6.921945
Sum squared resid	16137.68	Schwarz criterion		7.107895
Log likelihood	-571.4434	Hannan-Quinn criter.		6.997413
Durbin-Watson stat	1.574179			

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UMR 5281 ART-Dev – site Saint-Charles
rue Henri Serre – 34 090 Montpellier
tél. : 33 (0)4 67 14 71 07
artdev@univ-montp3.fr
<http://recherche.univ-montp3.fr/artdev>

